WeibullR - An R Package for Weibull Analysis for Reliability Engineers

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Abstract:
The WeibullR package provides a flexible data entry capability with three levels of usage. Quick Fit Functions, wblr object model, and technical back end functions. WeibullR should appeal to the newest practitioners to the R community as well as seasoned researchers willing to examine deeper aspects of analysis.

- WeibullR intends to provide a complete user friendly application in the R environment.
- The target audience is intended to be engineering and manufacturing practitioners, who might be introduced to R for the first time.
- C++ code greatly improves the speed of several complex looped calculations such as pivotal analysis, likelihood profiles, and third parameter optimizations.

Quick Fit functions:

Much of the detailed code required to generate regression lines, and confidence bounds on a plot with an informative legend are encapsulated in easy to use functions.

- Placing characteristics of the fit in the function name and use of reasonably expected defaults enables easy access to a complete analysis in one simple command line.

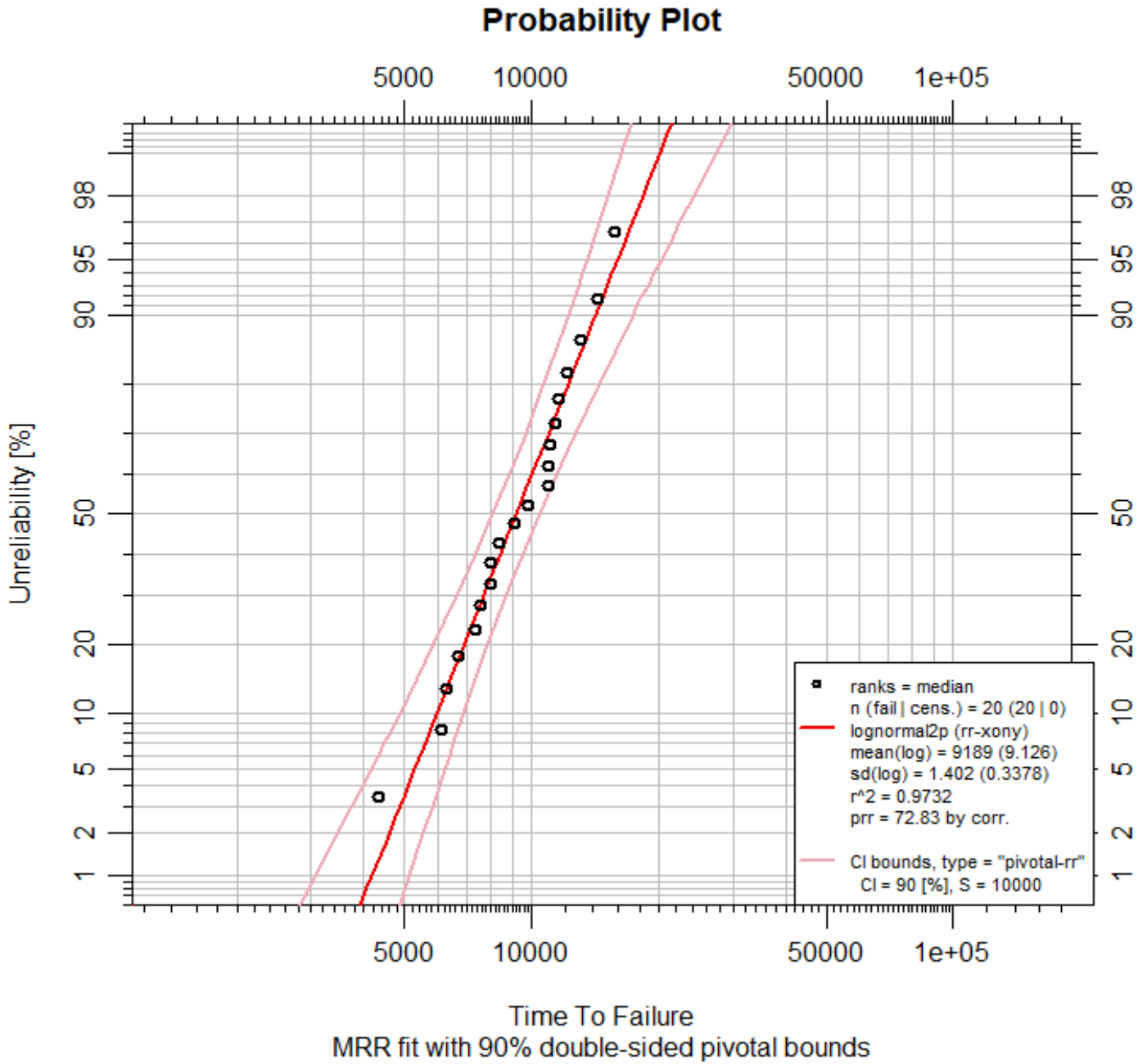
```
> MRRln2p(gears)
```

Mulog	Sigmalog	Rsqr	AbPval
9.1257399	0.3378295	0.9732135	72.8346303

Usage

```
MRRln2p(x, s=NULL, bounds=FALSE, show=FALSE)
```

MRRln2p(gears,T,T)



The wblr Object Model:

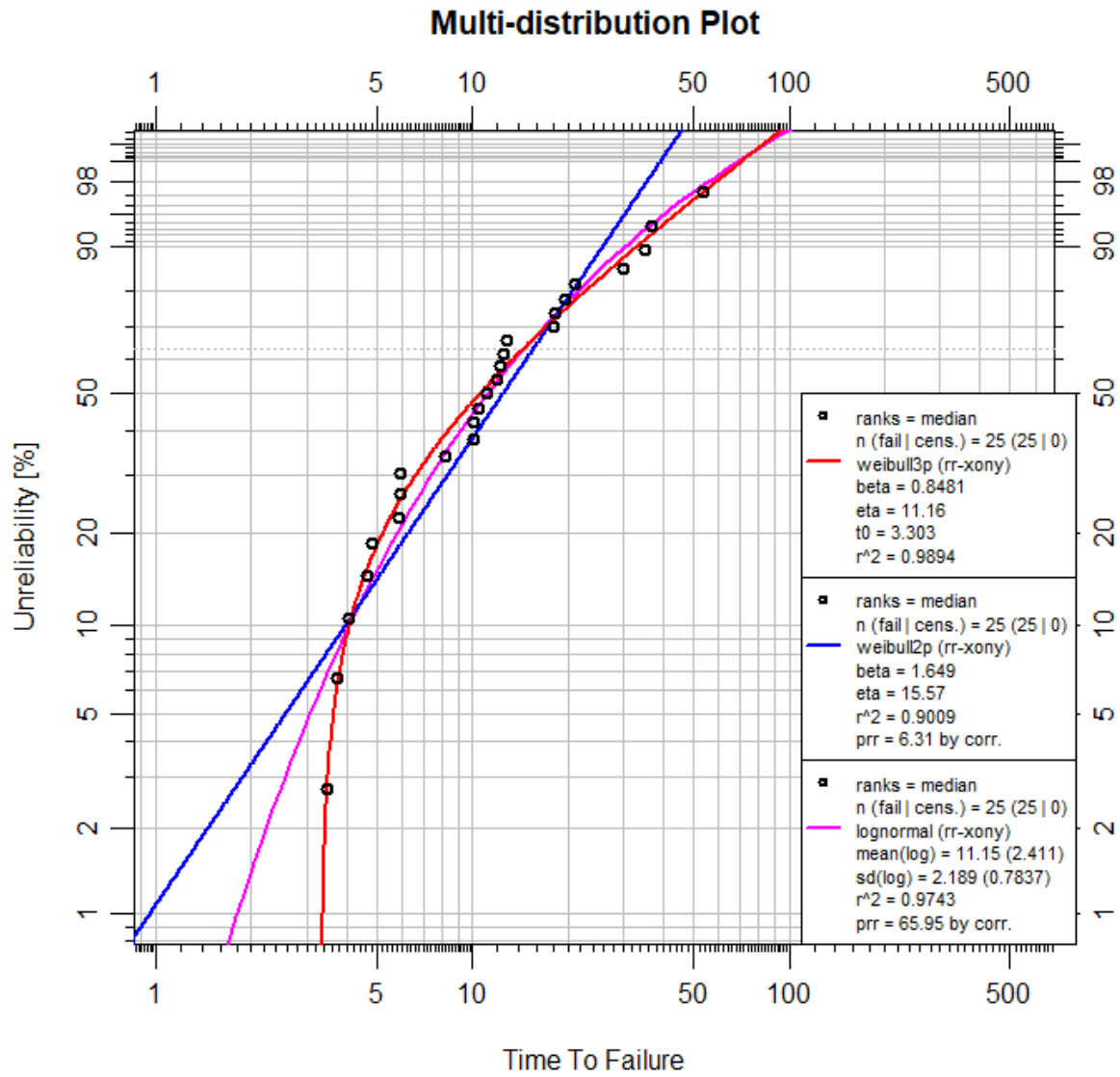
The wblr object model provides the user much more control over the analysis and plot generation. An object is created by passing the data into the wblr command.

```
my_object <- wblr(F3.13da)

my_object<- wblr.fit(my_object, dist="lognormal", col="magenta")

my_object<-wblr.fit(my_object, dist="weibull2p",  col="blue")

my_object<-wblr.fit(my_object, dist="weibull3p", col="red")
```



source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/Fig3.13multi.r")

Confidence Interval Bounds:

WeibullR implements four types of confidence interval bound calculations.:

- **Beta binomial bounds** are non-parametric and can be placed on any fit.
- **Pivitol bounds** are formed by way of a parametric bootstrap on rank regression fitting.
- For maximum likelihood estimation the classical normal-approximation bounds are formed utilizing solution of the negative hessian matrix (second derivatives of **Fisher information matrix**).
- A more complex calculation is also implemented based on the likelihood profile, also known as **likelihood ratio bounds**.

Likelihood Contours:

Of the four confidence bound methods implemented in WeibullR likelihood ratio bounds are considered to be most authoritative, yet are more challenging to calculate.

Contours are horizontal slices through the likelihood mound that is peaked by the maximum likelihood estimate. Contour slices are made at ratio values based on the relationship:

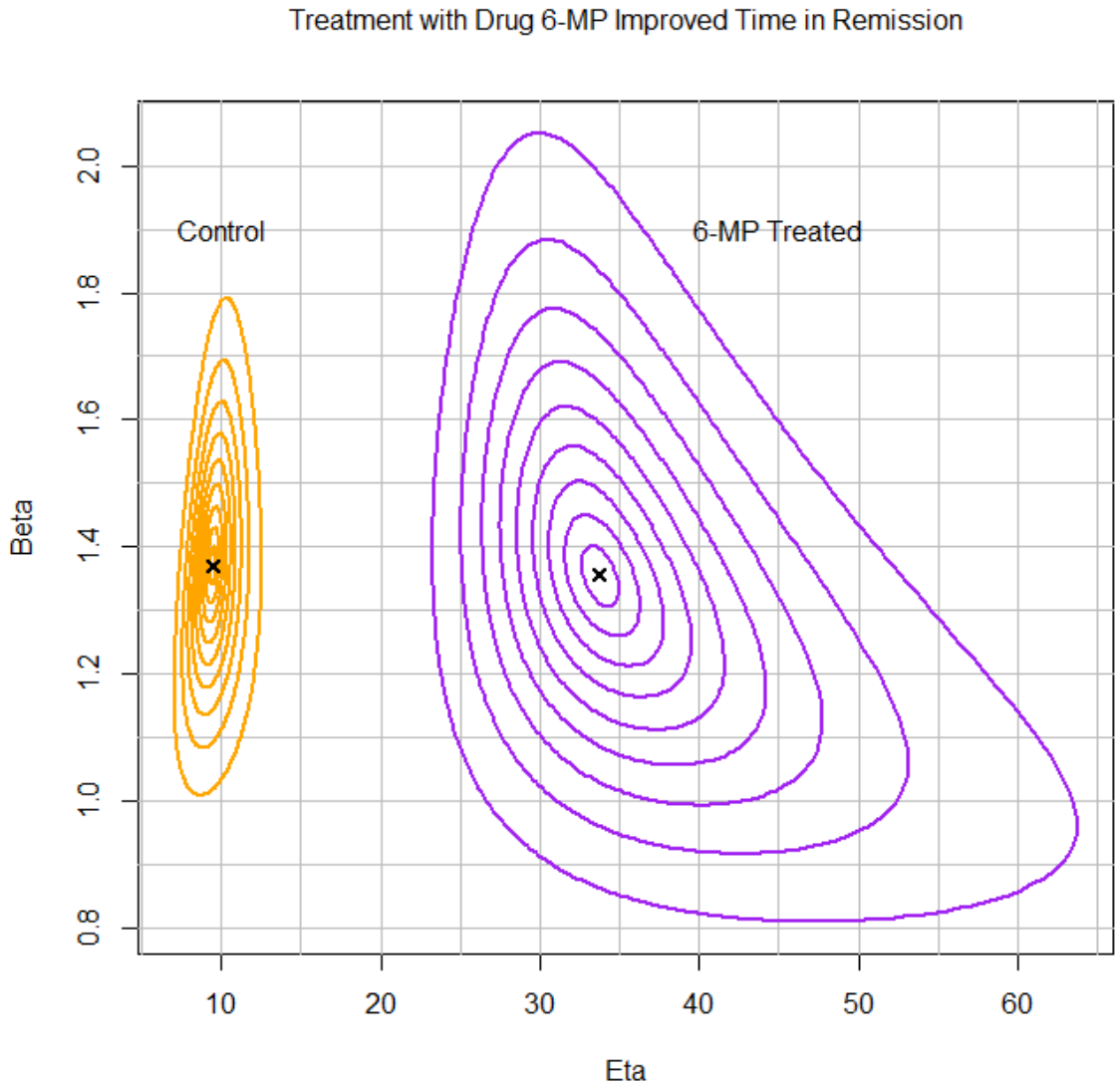
$$ratioLL = MLLx - qchisq(CL,dof)/2$$

Where the ratio is formed by subtraction of log-likelihood values. **MLLx** is the maximum log-likelihood estimate, **CL** is the confidence limit, and **dof** the degrees of freedom. Degrees of freedom are 1 for comparison of the model fit itself, or 2 when comparison is made against other data.

A famous dataset for comparisons found as MASS::gehan is used to compare an early chemotherapy drug 6-mp against a control.

Using S3 registration of R's core contour function contour maps can easily be generated from a wblr object

```
obj1<-wblr(control, col="orange")
obj2<-wblr(treat6mp, col="purple")
contour.wblr(list(obj1,obj2))
```

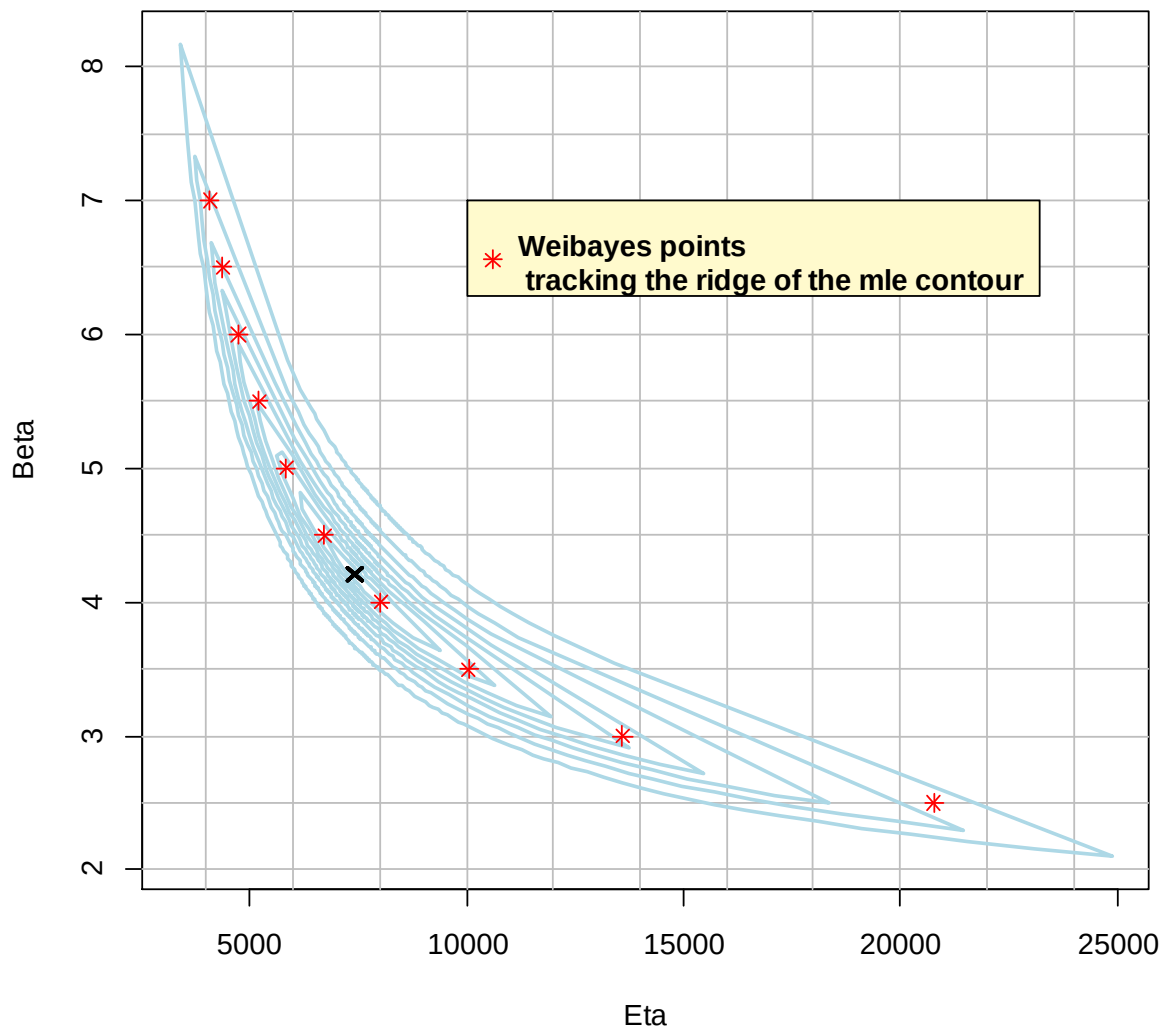


source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/compare_6mp.r")

"Weibayes", or 1-parameter Weibull calculation is a simplistic tool often relied upon by Reliability Engineers when minimal failure data is available.

```
eta_est<- sum((times^beta)/nfail)^(1/beta)
```

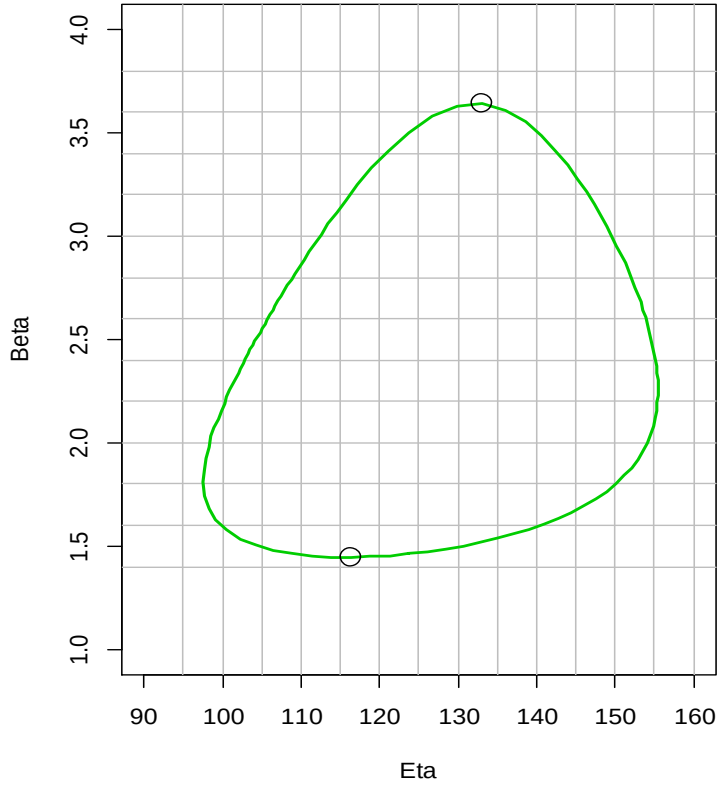
A particularly challenging contour calculation was encountered based on a submitted data set with 3 failure points and approximately 30,000 right-censored, suspension, values. After preparation of the contour map, it was felt that this could represent a good test case for the simplistic Weibayes calculation.

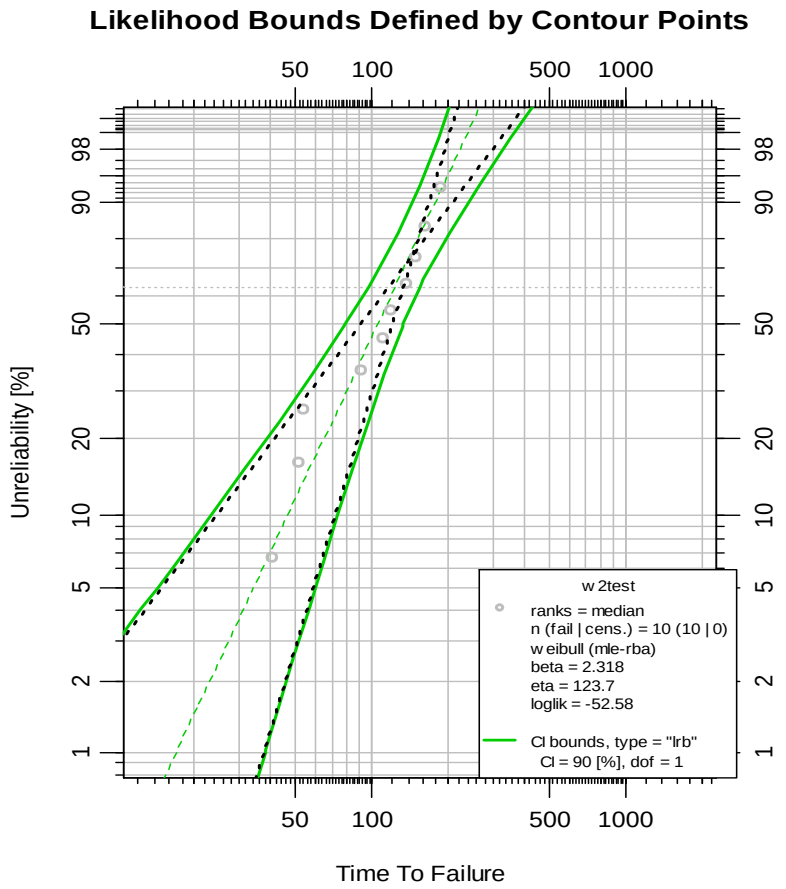


source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/weibayes_study.r")

Likelihood Ratio Bounds:

The points on a specific confidence level contour are used to define confidence interval bounds. Here the extreme Beta value points are shown to form asymptotes for the bounds on a 2-parameter model.

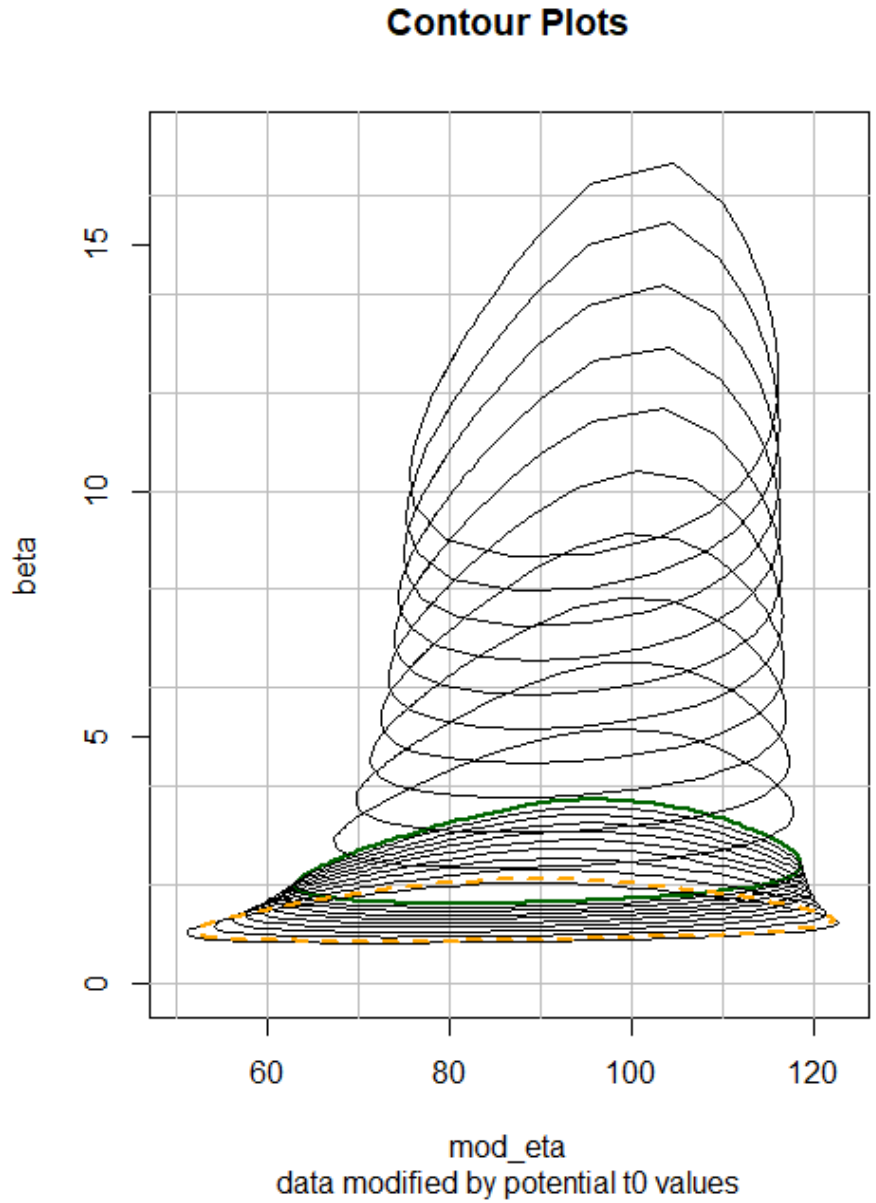


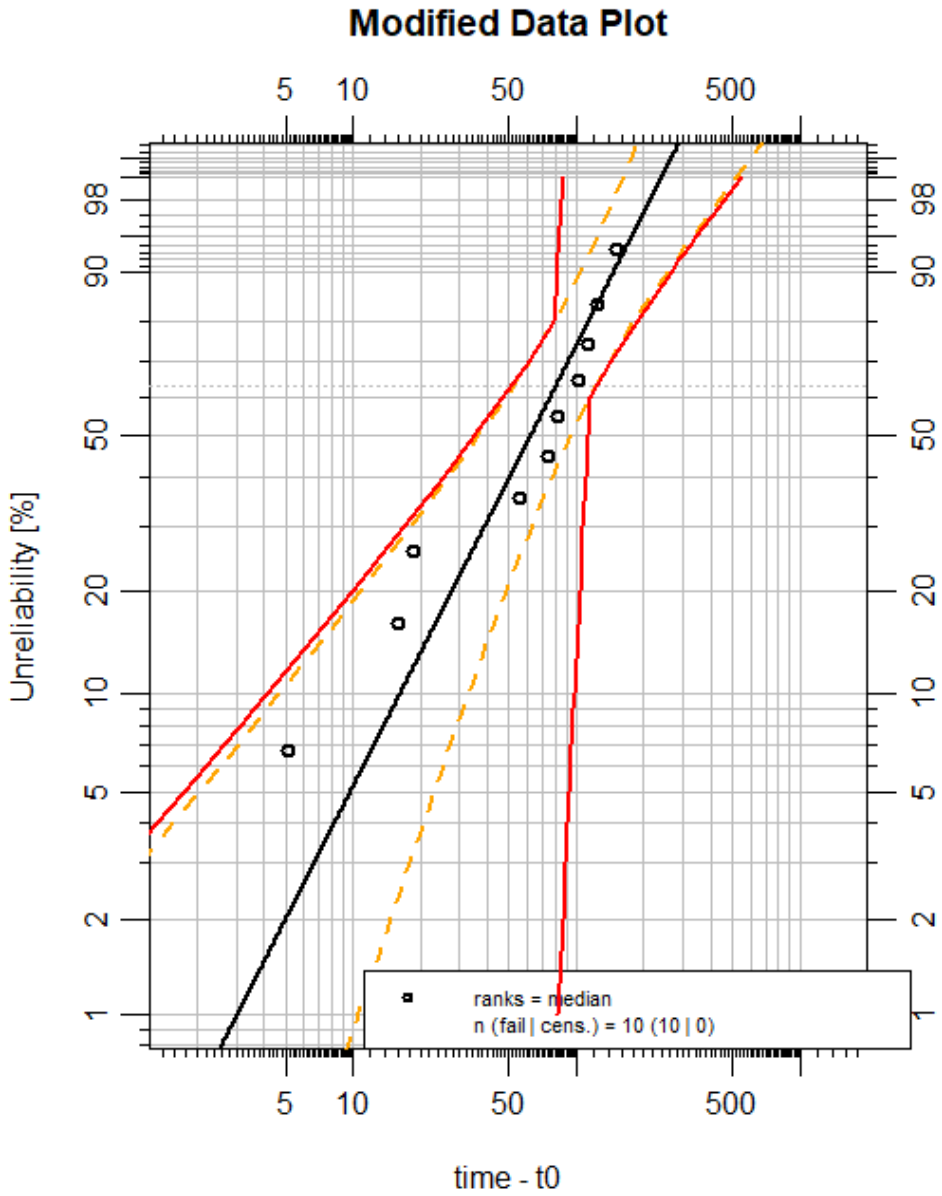


source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/contour2bounds.r")

Confidence bounds for 3 parameter models

- Initially avoided due to lack of documentation and example.
- Confidence intervals must be based on added uncertainty of the translation parameter, t0
- These bounds are still in the process of being implemented. My friends call this “research”.
- Latest development version 1.0.10.7 is available on GitHub and R-Forge.



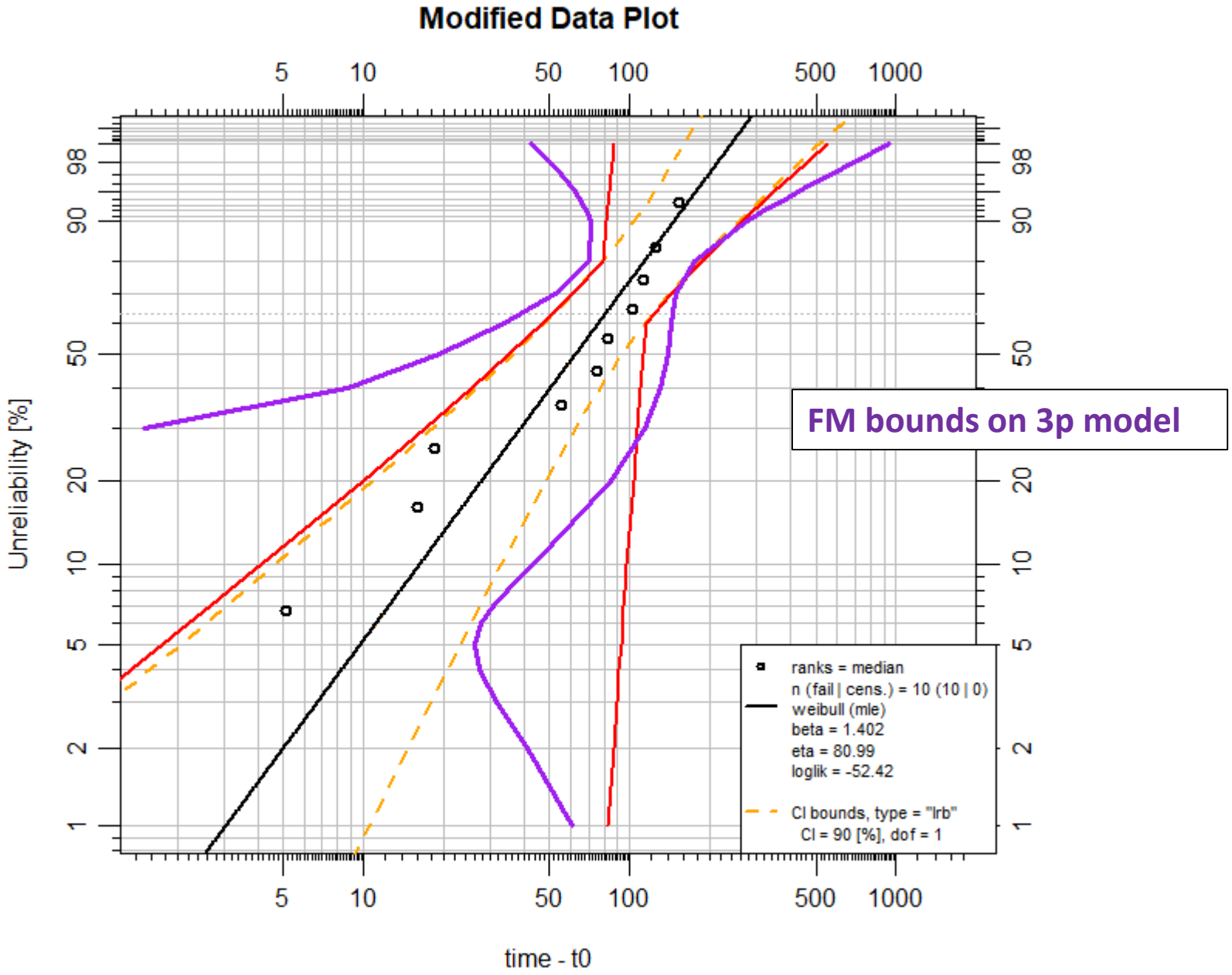


source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/LRbounds_3p.r")

Fisher Matrix bounds on 3 parameter models

- Implemented in Minitab software.
- Example calculations available in weibulltools package, by Tim-Gunnar Hensel.
- Blog by Stefan Gelissen

  http://blogs2.datall-analyse.nl/2016/02/17/rcode_three_parameter_weibull/



FM bounds on 3p model

source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/three_parameter_FM2.r")

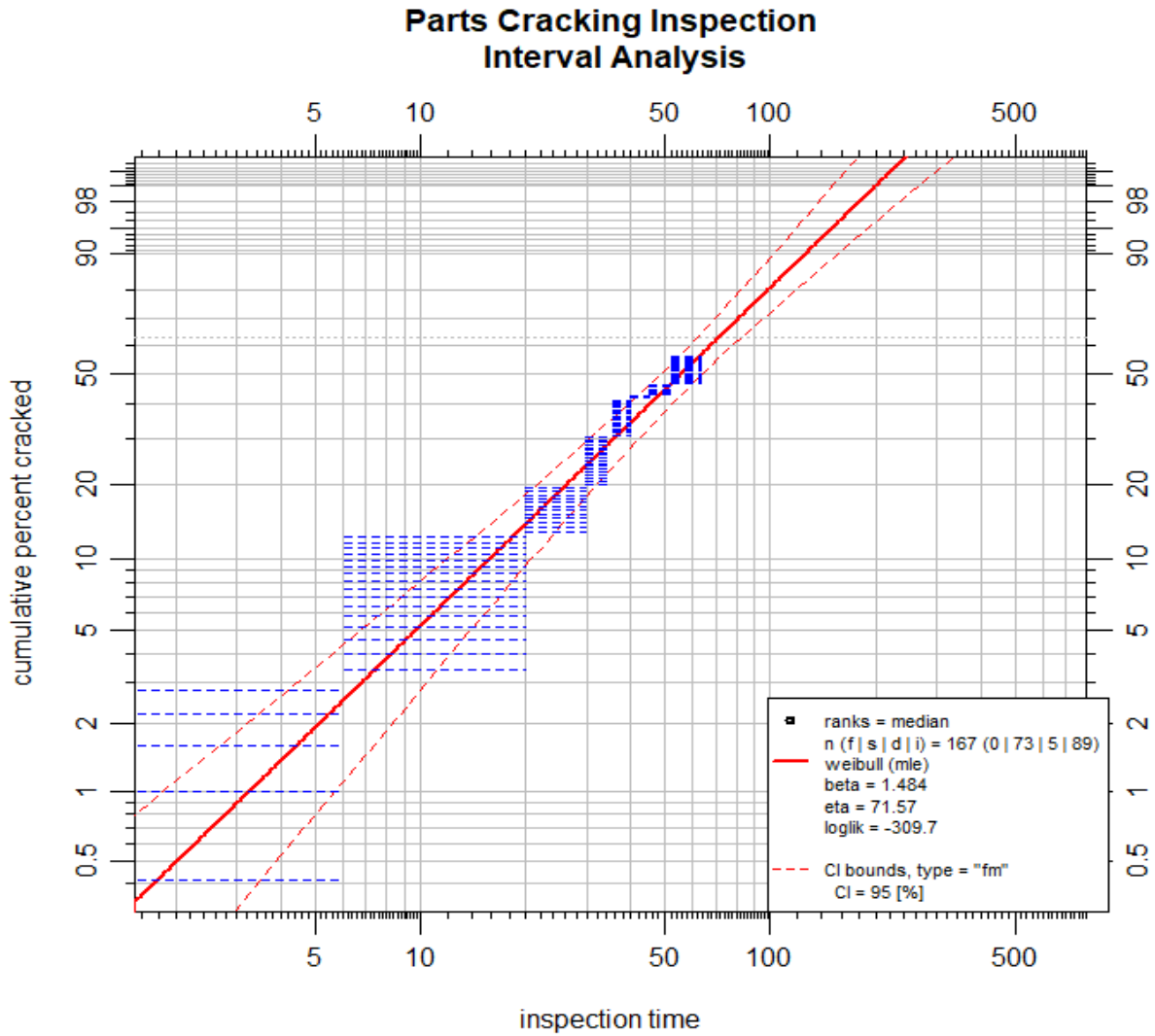
Grouped Data:

Grouped inspection data can be handled using an interval data input capability of WeibullR.

Part Cracking Data

Inspection (months)		Number		Cumulative
Start	End	Cracked	Cumulative	Percentage
0	6.12	5	5	2.99
6.12	19.92	16	21	12.6
19.92	29.64	12	33	19.8
29.64	35.40	18	51	30.5
35.40	39.72	18	69	41.3
39.72	45.24	2	71	42.5
45.24	52.32	6	77	46.1
52.32	63.48	17	94	56.3
63.48	+ Survived	73	167	

example by Wayne Nelson ,“Applied Life Data Analysis” , 1982



source("https://raw.githubusercontent.com/openrelia/WeibullR.gallery/master/scripts/inspection_intervals.r")

Warranty Data:

Warranty data is often analyzed as grouped inspection data. Products placed in service over a period such as a month form a group. Warranty claims are recorded over monthly intervals. As time progresses a layer-cake data form takes shape

				Units Placed in Service Each Month							
97	106	112	116	98	106	108	93	107	101	89	92
				Monthly Warranty Claims for Each Group							
9	5	12	7	5	3	6	6	10	9	6	4
5	4	3	1	6	3	0	3	1	3	3	
2	2	1	0	1	6	4	2	2	2		
2	3	4	2	1	2	3	3	1			
4	3	3	1	4	2	1	1				
1	1	2	1	1	1	1					
4	1	2	2	1	1						
2	4	0	4	3							
3	1	1	2								
2	3	1									
2	2										
2											

Proposed New Content

- For the warranty data, the code for data wrangling and analytical display should be encapsulated in easy to use functions.
- This analysis is often associated with Reliability Growth charts utilizing the power law.
- Considerable work is envisioned to provide useful functions to encapsulate considerations to be made with accelerated life testing.
- Several predictive analytics methods are a likely contribution
- A new package(s) that will depend on WeibullR. Likely names may be WeibullR.applications, WeibullR.specialties, WeibullR.ALT, WeibullR.RGA
- Collaborators are welcome!

Thank You

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